Do vaccinations reduce inequality in Covid-19 mortality? Evidence from England

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ABSTRACT

The Covid-19 pandemic has affected countries and regions to varying degrees. In this paper, I examine the socioeconomic determinants of Covid-19 mortality and study whether vaccinations have affected the relationship between those determinants and Covid-19 mortality rates across local areas in England. I use monthly data for 6791 Middle Layer Super Output Areas for the period from March 2020 to April 2021 and estimate a spatial correlations model with local authority and time fixed effects. To study whether vaccinations have affected the relationship between socioeconomic determinants and Covid-19 mortality, I extend the model to include interactions between socioeconomic variables and the lagged cumulative vaccination rate. I find that Covid-19 mortality is higher in areas that have an older population, a larger share of Asian population, higher population density, lower income, poorer pre-existing health and a larger share of employment in health and social care occupations. Vaccinations have weakened the links between mortality and these socioeconomic characteristics. These findings highlight the importance of making vaccines widely available and encouraging take-up, to reduce inequality in Covid-19 mortality across socioeconomic groups.

1. Background

The first confirmed case of Covid-19 in England was registered in York on January 30, 2020. By April 22, 2022, there had been 18, 475, 024 positive tests and 165, 445 deaths with Covid-19 in the death certificate. By the same date, 92% of the adult population had received at least one dose of a Covid-19 vaccine (https://coronavirus.data.gov.uk).

Behind these aggregate numbers, there is considerable regional variation. Fig. 1 shows the cumulative number of deaths per 100, 000 people and the percentage of the adult population vaccinated with at least one dose of a Covid-19 vaccine in different local areas. Cumulative mortality rates since the start of the pandemic vary considerably across the country and are lower in the South West. Vaccination take-up is generally high, but is lower in London, Sheffield, Leeds, Manchester, and Birmingham.

The Covid-19 pandemic has had a differential impact across socioeconomic groups. From the start of the pandemic, there has been evidence that people who live in the most deprived areas in England are more likely to die after contracting Covid-19 than those in the least deprived areas (ONS, 2020a). There is also evidence that Covid-19 infection and mortality rates are higher for Black and South Asian

ethnic groups (Mathur et al., 2021; ONS, 2020b).

These inequalities are not unique to the UK. Brandily et al. (2021) use data for French municipalities and find a negative relationship between income and mortality during the pandemic. Drefahl et al. (2020) use data for Sweden and find that individuals with lower income and lower education are more likely to die from Covid-19. Chen and Krieger (2021) use data for US counties and find that Covid-19 mortality is higher in counties with lower income, household crowding and predominantly non-white population. Desmet and Wacziarg (2022) also use data for US counties and find that Covid-19 cases and deaths are higher in counties with higher population density, more nursing home residents, lower income and a greater proportion of African Americans and Hispanics. Almagro and Orane-Hutchinson (2022) use data for New York City and find that the rate of positive Covid-19 tests is higher in neighbourhoods with a larger share of employment in transportation. Borjas (2020) also focuses on New York City and finds that the rate of positive tests is higher in neighbourhoods with lower income, larger households or predominantly Black population.

This growing literature on inequalities in Covid-19 mortality is related to the literature on mortality inequalities prior to the pandemic. Lewer et al. (2020) study inequality in premature mortality (below age

75) in small areas in England between 2003 and 2018. They find that one in three premature deaths can be attributed to socioeconomic inequality and that mortality inequality increased during the study period. Kraftman et al. (2021) conduct a similar study and also find that overall inequality increased in England during this period, with substantial differences across age groups. Mortality inequality fell for infants and children, but increased for older cohorts.

Vaccinations have kept mortality rates relatively low, even at times when infections were rising sharply. Fig. 2 shows the evolution of confirmed cases, mortality and vaccinations over time. The first wave of the pandemic peaked in April 2020 and is more visible in mortality data than in the number of cases because at that time tests were only available for patients admitted to hospital. The second wave peaked in January 2021 and is visible both in the number of cases and mortality. The number of cases has been increasing since about July 2021 and especially since December 2021. However, the increase in mortality has been much smaller than in previous waves due to the effectiveness of the vaccines.

The Covid-19 vaccination programme in the UK started in December 2020. Vaccines were rolled out in order of priority. The first six priority groups were residents and staff in care homes for older adults, those aged 80 or over and frontline health and social care workers, those aged 75 or over, those aged 70 or over and clinically extremely vulnerable individuals, those aged 65 or over, and adults aged 16 to 65 with certain medical conditions. Vaccines were then offered to the rest of the population, by age group.

The objective of this study is to examine the socioeconomic determinants of Covid-19 mortality rates in England and study whether Covid-19 vaccinations have affected the relationship between socioeconomic determinants and mortality.

2. Data and methods

2.1. Data sources

The empirical challenge in identifying the effect of socioeconomic characteristics on Covid-19 mortality is isolating the specific contribution of different factors. For example, we may find a negative correlation between income and mortality, but income may capture other factors, such as occupation, ethnicity or health. In this paper, I use data by Middle Layer Super Output Area (MSOA). There are 6, 791 MSOAs in England with an average population of about 8, 300 people and a median size of about 3 square km. These MSOAs are aggregated into 326 local authorities. This level of granularity allows me to include local authority fixed effects in the model and reduce omitted variable bias.

Data on Covid-19 mortality by MSOA are from the ONS and report the number of deaths with any mention of Covid-19 in the death certificate. These data are at monthly frequency and cover the period from March 2020 to April 2021. Data on Covid-19 vaccination rates are from https://coronavirus.data.gov.uk/. Data on the cumulative percentage of people who have received a first dose of a Covid-19 vaccine disaggregated by MSOA are only available for the most recent day and I use data downloaded on August 9, 2021. Daily data on vaccination rates from the start of the vaccination rollout are available at the local authority level, but not at the MSOA level.

I merge these data with data on socioeconomic characteristics. Table 1 presents descriptive statistics and the data sources. Data on ethnicity and household size are from the 2011 Census. Data on gender, age, population and density are from the ONS 2019 population estimates. Data on annual household income are from the ONS 2018 income estimates for small areas. Data on the average number of NHS outpatient appointments per person in 2019 are from the Hospital Episode
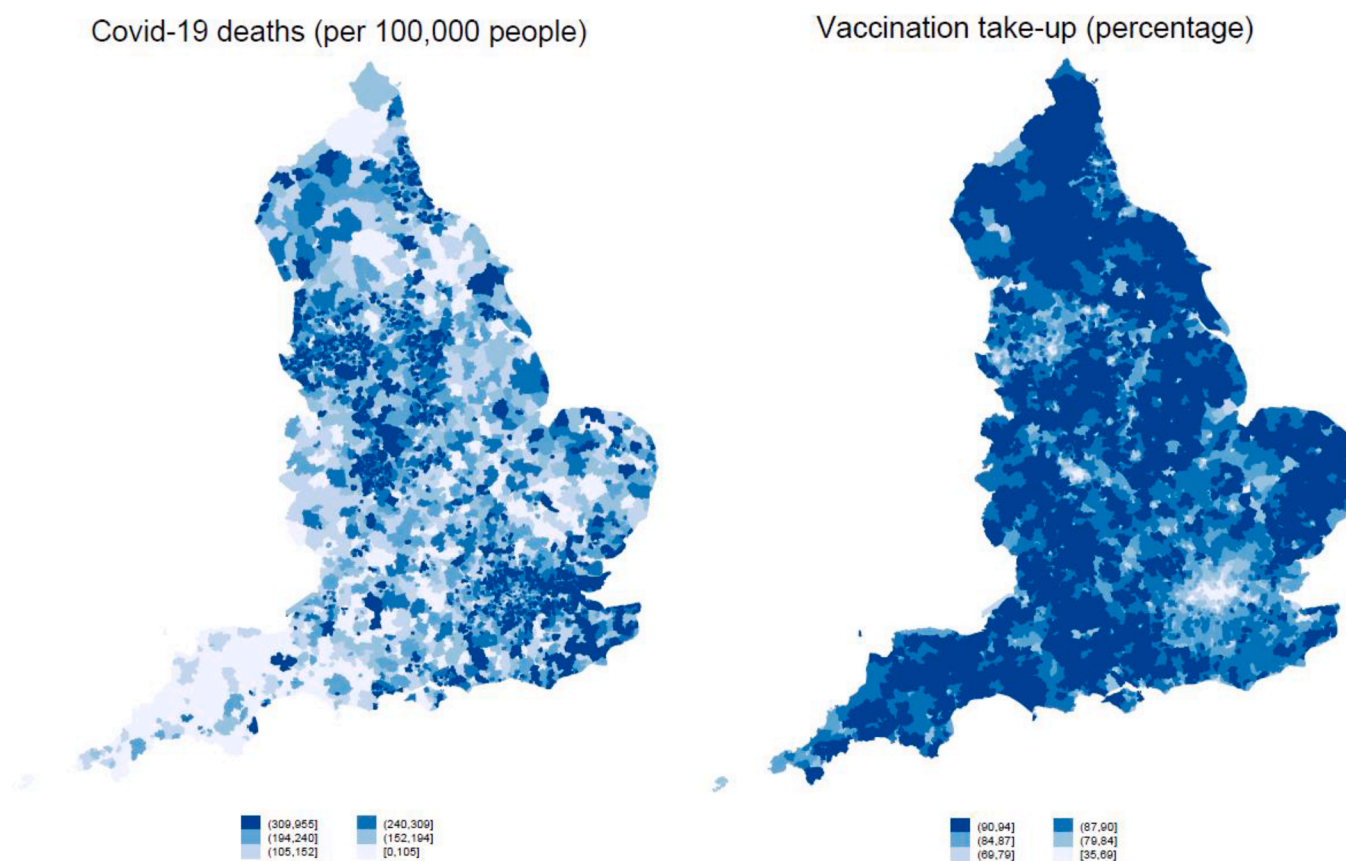

Fig. 1. Mortality and vaccinations by MSOA. Total number of deaths with a mention of Covid-19 in the death certificate, March 2020 to April 2021; ONS. Percentage of people aged 18+ who have received at least one dose of a Covid-19 vaccine, August 9, 2021; https://coronavirus.data.gov.uk.
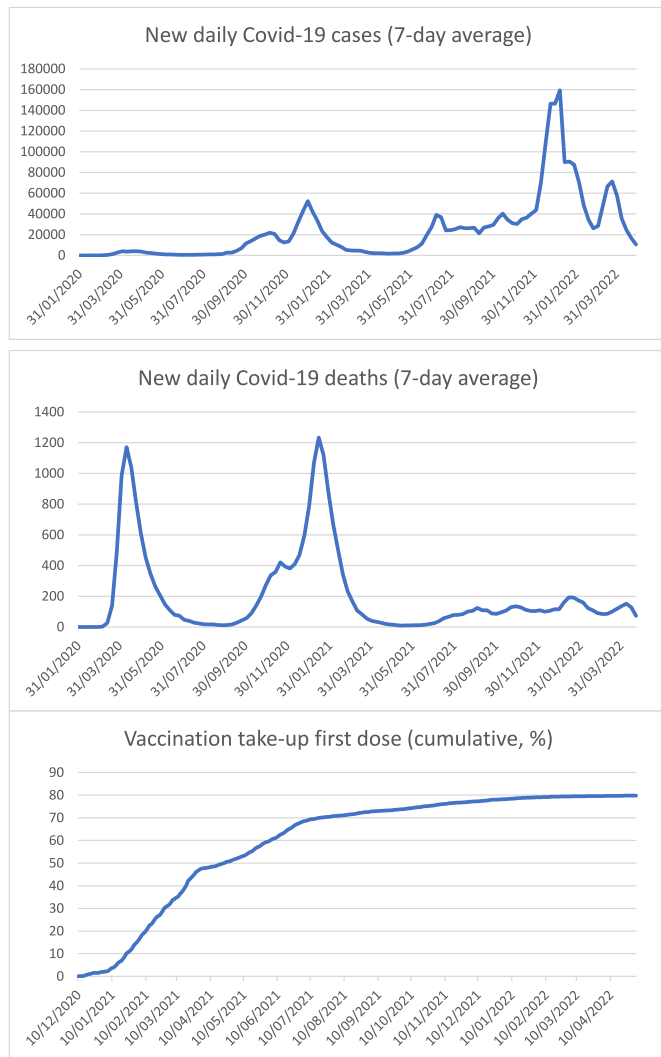
Fig. 2. Cases, mortality, and vaccinations over time. Cases: number of people with at least one positive Covid-19 test result, by specimen date. Deaths: number of daily deaths with Covid-19 in the death certificate, by date of death. Vaccination take-up: percentage of people aged 18+ who have received a Covid-19 vaccination, by date reported. https://coronavirus.data.gov.uk.

Statistics. These health data reflect the general health of the local population, including the prevalence of comorbidities, better than self-reported measures of health available in the Census and in survey data. Data on occupation by MSOA are from the 2011 Census. I calculate the shares of employment in three types of occupations — health and social care, transport and construction.

All the data used are aggregate anonymous data from public sources, so ethical approval was not required.

2.2. Statistical methods

I estimate a spatial correlations model to examine the socioeconomic determinants of Covid-19 mortality:

$$Y_{m,i,t} = \beta X_m + \gamma_i + \delta_t + \varepsilon_{m,i,t} \qquad (1)$$

The outcome variable is the number of Covid-19 deaths per 100,000 people in MSOA m, in local authority i during month t. The vector of socioeconomic characteristics X_m includes: percent female, percent age 60 and over, percent Black/African/Caribbean/Black British, percent Asian/Asian British, log population density, log average household size, log annual household income, the average number of NHS outpatient

Table 1
Descriptive statistics.

	Mean	Standard deviation	Source
Panel– 6791 MSOAs, 326 LAs, March 2020 to April 2021			
Covid-19 deaths per 100,000 people (MSOA)	14.984	27.461	ONS; ONS 2019 population estimates
Cumulative percent vaccinated with a first dose of a Covid-19 vaccine (LA)	9.758	18.545	https://coronavirus.data. gov.uk/(monthly average of daily data)
Cross-section - 6791 MSOAs			
Percent female	50.666	1.688	ONS 2019 population estimates
Percent age 60 and over	24.691	8.240	ONS 2019 population estimates
Percent Black/African/ Caribbean/Black British	3.260	6.321	2011 Census
Percent Asian/Asian British	7.249	12.054	2011 Census
Log population density	2.819	1.519	ONS 2019 population estimates
Log household size	0.859	0.094	2011 Census
Log annual household income	10.665	0.219	ONS 2018 income estimates for small areas
Number of NHS outpatient appointments per person	2.203	0.518	NHS Digital Hospital Episode Statistics, outpatient appointments by patient MSOA in 2019; ONS 2019 population estimates
Percent health occupations	6.598	1.778	Number of usual residents aged 16+ in employment by occupation (4 digits); 2011 Census
Percent transport occupations	3.550	1.485	2011 Census
Percent construction occupations	5.914	1.844	2011 Census

appointments per person and the percentage of employment in health and social care, transport and construction occupations. Local authority fixed effects (γ_i) capture time-invariant local characteristics and time fixed effects (ρ_t) capture time-varying factors that affect all local areas in a similar way, for example, seasonal effects. I weight each MSOA by its total population.

To account for temporal autocorrelations and spatial autocorrelations between neighbouring local areas, I compute Conley standard errors (Conley, 1999) allowing for spatial heteroskedasticity in a radius of 5 km, using code provided by Colella et al. (2019).

Motivated by Fig. 2, I estimate the model separately for four different phases:

- Phase 1 covers the period from March to May 2020 and corresponds to the first wave of the pandemic and the first national lockdown;
- Phase 2 covers the period from November to December 2020 and corresponds to the second national lockdown and the subsequent tier system of local restrictions;
- Phase 3 covers the period from January to February 2021 and corresponds to the third national lockdown;
- Phase 4 covers the period from March to April 2021, during which the government gradually eased lockdown restrictions and continued the vaccine rollout.

To examine whether vaccinations have affected the relationship between socioeconomic factors and mortality, I extend the model to include the lagged cumulative vaccination rate in local authority i ($vaccination_{it-1}$) and interactions between each socioeconomic variable in the vector X_m and the lagged cumulative vaccination rate:

$$Y_{m,i,t} = \beta X_m + \mu vaccinationr_{it-1} + \eta vaccinationr_{it-1} \times X_m + \gamma_i + \delta_t + \varepsilon_{m,i,t} \tag{2}$$

The cumulative vaccination rate is included with a one-month lag, to allow immunity to develop after vaccination and to reflect the time lag between infections and mortality. I estimate the model for phase 4, when cumulative vaccination rates had reached higher levels.

Finally, to examine the socioeconomic determinants of vaccination take-up, I estimate the following model for the cross-section of MSOAs:

$$vaccinationr_{m,i} = \beta X_m + \gamma_i + \varepsilon_{m,i} \tag{3}$$

The dependent variable is the cumulative percentage of the population vaccinated with a first dose of a Covid-19 vaccine as of August 9, 2021 in MSOA m in local authority i. The vector X_m includes the same socioeconomic variables as models (1) and (2).

3. Results

Table 2 reports the results of estimating model (1) for the four phases of the pandemic. Covid-19 mortality is higher in MSOAs where the population has poor health. This is consistent with evidence that certain

heath conditions — such as obesity, severe asthma and uncontrolled diabetes — lead to more severe disease and higher mortality (Bhaskaran et al., 2021; Harrison et al., 2020).

Looking at the effect of occupation, there is a positive link between mortality and employment in health and social care occupations. This link is no longer apparent in phase 4, when the vaccines rollout was well under way. There is no consistent link between mortality and employment in transport and construction occupations.

As expected, Covid-19 mortality is higher in MSOAs with an older population. The link with ethnicity is less clear — MSOAs with a larger share of Asian population have higher mortality, but there is no clear link between mortality and the share of Black population. Mortality is higher in MSOAs with higher population density and lower household income.

The bottom of Table 2 reports the results of tests for equality of the coefficients in each of the first three phases of the pandemic and in phase 4. The links between mortality and age, ethnicity, population density, income, pre-existing health and employment in health and social care occupations are weaker in phase 4 than in earlier phases. A possible explanation is that vaccinations have worked as a leveller and reduced inequality in Covid-19 mortality across socioeconomic groups.

To test this hypothesis, I extend the model to include the one-month lagged cumulative vaccination rate by local authority and an interaction of the vaccination rate with each socioeconomic variable. Table 3 reports the results. An increase in the cumulative vaccination rate by 10 percentage points reduces Covid-19 mortality by about 18 deaths per 100, 000 people. The coefficients on the interactions between the vaccination rate and the percentage of the population age 60 and over, the share of Asian population, log population density, log annual household income and the number of outpatient appointments per person are of the opposite sign to the main effects. This supports the hypothesis that vaccinations have weakened the links between these factors and Covid-19 mortality.

Table 4 reports the results on the socioeconomic determinants of vaccination take-up. Vaccination rates are higher in MSOAs where the

Table 2
Socioeconomic determinants of mortality rates.

Dependent variable: Covid-19 deaths per 100,000 people				
	Phase 1	Phase 2	Phase 3	Phase 4
Percent female	0.258*	0.195	0.500**	−0.131***
	(0.153)	(0.150)	(0.212)	(0.048)
Percent age 60 and over	0.821***	0.570***	1.296***	0.147***
	(0.069)	(0.054)	(0.097)	(0.020)
Percent Black/ African/ Caribbean/Black British	−0.063	−0.177***	−0.108	−0.005
	(0.104)	(0.042)	(0.099)	(0.020)
Percent Asian/Asian British	0.059	0.093***	0.265***	0.036***
	(0.044)	(0.029)	(0.049)	(0.012)
Log population density	0.948***	1.096***	1.876***	0.254***
	(0.244)	(0.211)	(0.381)	(0.078)
Log household size	1.996	−1.928	−2.952	0.296
	(4.116)	(2.874)	(4.741)	(1.173)
Log annual household income	−20.190***	−11.191***	−32.962***	−4.559***
	(2.967)	(1.919)	(3.030)	(0.781)
Outpatient appointments per person	3.619***	2.017**	3.623**	0.716**
	(1.277)	(0.886)	(1.497)	(0.327)
Percent health occupations	1.027***	0.351***	1.118***	0.035
	(0.209)	(0.136)	(0.280)	(0.059)
Percent transport occupations	−0.134	0.617***	−0.088	0.204**
	(0.437)	(0.231)	(0.363)	(0.102)
Percent construction occupations	−0.797***	−0.090	0.108	0.014
	(0.259)	(0.177)	(0.279)	(0.065)
Observations	20,373	13,582	13,582	13,582
R-squared	0.377	0.261	0.287	0.183
	p-value of test for equality of coefficient to phase 4			
Percent age 60 and over	0.000	0.000	0.000	
Percent Asian/Asian British	0.498	0.055	0.000	
Log population density	0.004	0.000	0.000	
Log annual household income	0.000	0.001	0.000	
Outpatient appointments per person	0.007	0.142	0.040	
Percent health occupations	0.000	0.024	0.000	

Spatial (5 km) standard errors in parentheses. Regressions include local authority and time fixed effects. Phase 1: March to May 2020; Phase 2: November and December 2020; Phase 3: January and February 2021; Phase 4: March and April 2021. ***p < 0.01, **p < 0.05, *p < 0.1.

Table 3
Interaction with vaccination rate.

Dependent variable: Covid-19 deaths per 100,000 people		
	Main Effect	Interaction
Lagged cumulative vaccination rate	−1.845***	–
	(0.525)	
Percent female	−0.178	0.001
	(0.162)	(0.004)
Percent age 60 and over	0.360***	−0.006***
	(0.057)	(0.001)
Percent Black/African/Caribbean/Black British	−0.061	0.002
	(0.046)	(0.001)
Percent Asian/Asian British	0.095***	−0.002**
	(0.035)	(0.001)
Log population density	1.317***	−0.027***
	(0.261)	(0.006)
Log household size	0.980	−0.071
	(3.341)	(0.087)
Log annual household income	−10.512***	0.179***
	(1.915)	(0.050)
Outpatient appointments per person	1.990***	−0.045***
	(0.630)	(0.014)
Percent health occupations	−0.167	0.007
	(0.162)	(0.004)
Percent transport occupations	0.381*	−0.004
	(0.231)	(0.005)
Percent construction occupations	0.102	−0.003
	(0.157)	(0.004)
Observations	13,582	
R-squared	0.192	

Spatial (5 km) standard errors in parentheses. Regressions include local authority and time fixed effects. Sample restricted to phase 4: March and April 2021. ***p < 0.01, **p < 0.05, *p < 0.1.

Table 4
Socioeconomic determinants of vaccination rates.

Dependent variable: Cumulative vaccination rate 9th August 2021	
Percent female	0.557***
	(0.057)
Percent age 60 and over	0.419***
	(0.013)
Percent Black/African/Caribbean/Black British	−0.312***
	(0.017)
Percent Asian/Asian British	−0.197***
	(0.013)
Log population density	0.107**
	(0.052)
Log household size	10.483***
	(1.375)
Log annual household income	21.010***
	(0.833)
Outpatient appointments per person	3.911***
	(0.311)
Percent health occupations	−0.046
	(0.058)
Percent transport occupations	0.343***
	(0.090)
Percent construction occupations	0.572***
	(0.056)
Observations	6791
R-squared	0.917

Robust standard errors in parentheses. Regression includes local authority fixed effects. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

population is older or has poorer pre-existing health, reflecting the priority order used in the vaccines rollout. There is a clear link between ethnicity and vaccination take-up, with lower vaccination rates in MSOAs with larger shares of Black or Asian population. There is also a clear link between vaccination rates and income, with higher vaccination rates in high-income MSOAs.

4. Discussion

I find that Covid-19 mortality rates are higher in local areas with an older population, a larger share of Asian population, higher population density, lower income, poorer pre-existing health and a larger share of employment in health and social care occupations. Vaccinations have weakened the links between mortality and these socioeconomic characteristics. The vaccination programme has only partially targeted groups with higher mortality rates. It has prioritised the elderly, health care workers and those with certain medical conditions. However, it has not targeted low-income individuals and Black and Asian ethnic groups. Vaccination take-up is lower in local areas with lower income and a larger share of Black or Asian population. Despite these inequalities in take-up, vaccinations have acted as a leveller, reducing inequality in Covid-19 mortality across socioeconomic groups.

This study makes two contributions. First, it uses a fine level of geographic disaggregation to study the links between Covid-19 mortality and socioeconomic characteristics. Second, it highlights the role of vaccinations in reducing inequalities in Covid-19 mortality, despite inequalities in vaccination take-up. There is a growing literature on socioeconomic inequalities in Covid-19 mortality, which is partially summarised in the background section. There are also studies reporting inequalities in vaccination take-up. Woolf et al. (2021) report higher vaccine hesitancy among ethnic minority communities in the UK. Liao (2021) uses data for counties in Illinois and finds that vaccination coverage is lower in poorer counties and those with a higher percentage of Black or Hispanic population. However, to the best of my knowledge, the role of vaccinations in reducing inequalities in Covid-19 mortality has not been highlighted in previous studies.

These findings have important policy implications. Nationally, they highlight the importance of making vaccines widely available and

encouraging take-up, particularly for groups that have higher mortality rates and have not been prioritised by the vaccination programme, such as low-income individuals and those with Asian ethnicity. Internationally, it is important to make vaccines widely available in emerging and developing countries. This would reduce inequality in the impact of Covid-19 across the world.

This study is subject to limitations related to data availability. Data on ethnicity, household size and occupation shares are from the 2011 Census, because data from the 2021 Census are not yet available. To check whether these characteristics have been stable over time, I use data on ethnicity and occupation (2-digits) at the local authority level from the Annual Population Survey for 2011 and 2021. I find that the percentage of non-white population has been broadly stable over this period, with a correlation coefficient of 0.94 between the 2011 and 2021 data. For the share of employment in different occupations, the correlation coefficient is smaller at 0.68. It would have been preferable to use more updated data on occupation shares. An additional limitation is that monthly data on vaccination rates are only available at the local authority level. Data by MSOA would have matched the level of disaggregation of the other variables used in the analysis. There is also a concern that estimates of household income at small area level may suffer from measurement error. Finally, data on Covid-19 mortality by MSOA are only available until April 2021, when many adults in England were not yet eligible for Covid-19 vaccination. Having data for a longer period would allow more precise estimation of the effect of vaccinations on mortality inequality.

References

Almagro, M., Orane-Hutchinson, A., 2022. The determinants of the differential exposure to Covid-19 in New York City and their evolution over time. J. Urban Econ. Insight 127.
Bhaskaran, K., Bacon, S., Evans, S.J.W., Bates, C.J., Rentsch, C.T., MacKenna, B., et al., 2021. Factors associated with deaths due to COVID-19 versus other causes: population-based cohort analysis of UK primary care data and linked national death registrations within the OpenSAFELY platform. Lancet Region. Health Eur. 6.
Borjas, G.J., 2020. Demographic determinants of testing incidence and Covid-19 infections in New York City neighborhoods. Covid Econ.: Vetted Real-Time Pap. 3. April 10.
Brandily, P., Brébion, C., Briole, S., Khoury, L., 2021. A Poorly Understood Disease? the Impact of COVID-19 on the Income Gradient in Mortality over the Course of the Pandemic, vol. 140. European Economic Review.
Chen, J.T., Krieger, N., 2021. Revealing the unequal burden of COVID-19 by income, race/ethnicity, and household crowding: US county versus zip code analyses. J. Publ. Health Manag. Pract. 27, S43–S56.
Colella, F., Lalive, R., Sakalli, S.O., Thoenig, M., 2019. Inference with Arbitrary Clustering, vol. 12584. IZA DP.

Conley, T., 1999. GMM estimation with cross sectional dependence. J. Econom. 92 (1), 1–45.

Desmet, K., Wacziarg, R., 2022. Understanding spatial variation in COVID-19 across the United States. J. Urban Econ. Insight 127.

Drefahl, S., Wallace, M., Mussino, E., et al., 2020. A population-based cohort study of socio-demographic risk factors for COVID-19 deaths in Sweden. Nat. Commun. 11, 5097.

Harrison, S.L., Fazio-Eynullayeva, E., Lane, D.A., Underhill, P., Lip, G.Y.H., 2020. Comorbidities associated with mortality in 31,461 adults with COVID-19 in the United States: a federated electronic medical record analysis. PLoS Med. 17 (9).

Kraftman, L., Hardelid, P., Banks, J., 2021. Age specific trends in mortality disparities by socio-economic deprivation in small geographical areas of England, 2002-2018: a retrospective registry study. Lancet Region. Health Eur. 7.

Lewer, D., Jayatunga, W., Aldridge, R.W., Edge, C., Marmot, M., Story, A., Hayward, A., 2020. Premature mortality attributable to socioeconomic inequality in England between 2003 and 2018: an observational study. Lancet Public Health 5 (1).

Liao, T.F., 2021. Social and economic inequality in coronavirus disease 2019 vaccination coverage across Illinois counties. Sci. Rep. 11, 18443.

Mathur, R., Rentsch, C.T., Morton, C.E., et al., 2021. Ethnic differences in SARS-CoV-2 infection and COVID-19-related hospitalisation, intensive care unit admission, and death in 17 million adults in England: an observational cohort study using the OpenSAFELY platform. Lancet 397, 1711–1724.

ONS, 2020a. Deaths involving COVID-19 by local area and socioeconomic deprivation: deaths occurring between 1 March and 31 July 2020. Office Nat. Stat. August 28, 2020 https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsa ndmarriages/deaths/bulletins/deathsinvolvingcovid19bylocalareasanddepriva tion/deathsoccurringbetween1marchand31july2020.

ONS, 2020b. Why Have Black and South Asian People Been Hit Hardest by COVID-19? Office for National Statistics. December 14, 2020.

Woolf, K., McManus, I.C., Martin, C.A., Nellums, L.B., Guyatt, A.L., Melbourne, C., et al., 2021. Ethnic differences in SARS-CoV-2 vaccine hesitancy in United Kingdom healthcare workers: results from the UK-REACH prospective nationwide cohort study. Lancet Region. Health Eur. 9.